

IN THE SPECIFICATION

Please replace paragraph 9 with the following paragraph:

In still another aspect of the present invention, a method for making a phosphor comprises: (a) providing amounts of oxygen-containing compounds of magnesium; europium; manganese; at least another alkaline-earth metal, which is selected from the group consisting of barium, strontium, and calcium; and at least a Group-IIIB metal selected from the group consisting of Al, Ga, In, and combinations thereof; (b) mixing together the oxygen-containing compounds to form a mixture; and (c) firing the mixture at a temperature between about 1000 $^{\circ}\text{C}$ and about 1750 $^{\circ}\text{C}$ under a reducing atmosphere for a sufficient period of time to convert the mixture to a phosphor having a formula of $\text{AMgD}_{10}\text{O}_{17}:\text{Eu}^{2+}, \text{Mn}^{2+}$; wherein A is said at least another alkaline-earth metal; and D is said at least a Group-IIIB metal.

Please replace paragraph 26 with the following paragraph:

In still another embodiment, a portion of Mg is substituted with Zn in ~~[[a mount]]~~ an amount from about 0.01 atom percent to about 99.99 atom percent of the combined Mg, Mn, and Zn ions. In yet another embodiment of the present invention, the level of Zn is from about 0.01 to about 50, preferably from about 0.01 to about 20 atom percent of the combined Mg, Mn, and Zn ions.

Please replace paragraph 27 with the following paragraph:

A phosphor of the present invention can be produced by a dry or a wet method. The dry method comprises: (a) providing amounts of oxygen-containing compounds of magnesium; europium; manganese; at least another alkaline-earth metal, which is selected from the group consisting of barium, strontium, and calcium; and at least a Group-IIIB

metal selected from the group consisting of Al, Ga, In, and combinations thereof; (b) mixing together the oxygen-containing compounds to form a mixture; and (c) firing the mixture at a temperature between about 1000 $[[C]]^{\circ}\text{C}$ and about 1600 $[[C]]^{\circ}\text{C}$ under a reducing atmosphere for a sufficient period of time to convert the mixture to a phosphor having a formula of $(A_{1-a}Eu_a)(Mg_{1-b}Mn_b)D_{10}O_{17}$; wherein A is said at least another alkaline-earth metal, D is said at least a Group-IIIB metal, $0.001 < a = 0.5$, and $0.001 < b = 0.3$. A firing time in a range from about 1 minute to about 10 hours is adequate. It should be recognized that a selected firing time depends, to some extent and among other things, the amount of material to be processed, the size and/or design of the heating device that is used to accomplish the firing, the degree of mixing of the solid material during firing, and the degree of contact between the gas and solid phases. Preferably, the firing temperature is in the range from about 1400 $[[C]]^{\circ}\text{C}$ to about 1600 $[[C]]^{\circ}\text{C}$. The reducing atmosphere is selected from the group consisting of hydrogen, carbon monoxide, ammonia, and mixtures thereof with an inert gas selected from the group consisting of nitrogen, helium, neon, argon, krypton, and xenon. The reducing atmosphere can be a product of the combustion of carbon in limited amount of air (also known as incomplete combustion). The reducing atmosphere also can be products of decomposition of compounds that give at least one of hydrogen and carbon monoxide. For example, ammonia or hydrazine can decompose to give nitrogen and hydrogen at high temperature (greater than about 700 $[[C]]^{\circ}\text{C}$).

Please replace paragraph 32 with the following paragraph:

The oxygen-containing compounds may be mixed together by any mechanical method including, but not limited to, stirring or blending in a high-speed blender or a ribbon blender. The oxygen-containing compounds may be combined and pulverized together in a bowl mill, a hammer mill, or a jet mill. The mixing may be carried out by wet milling especially when the mixture of the oxygen-containing compounds is to be made into a solution for subsequent precipitation. If the mixture is wet, it may be dried

first before being fired to a temperature in the range from about 1000 $^{\circ}\text{C}$ to about 1600 $^{\circ}\text{C}$. The drying may be carried out at ambient atmosphere or under a vacuum. The heating may be conducted in a batchwise or continuous process, preferably with a stirring or mixing action to promote good gas-solid contact. The firing time depends on the quantity of the mixture to be fired, the rate of gas conducted through the firing equipment, and the quality of the gas-solid contact in the firing equipment. Typically, a heating time from about 1 minute to about 10 hours is adequate.

Please replace paragraph 34 with the following paragraph:

The mixture was fired under an atmosphere comprising 2 percent (by volume) hydrogen in nitrogen, at a temperature of 1550 $^{\circ}\text{C}$, for about 4 hours. The phosphor had a formula of $(\text{Sr}_{0.7}\text{Eu}_{0.3})(\text{Mg}_{0.8}\text{Mn}_{0.2})\text{Al}_{10}\text{O}_{17}$, as determined from the various amounts used in the preparation of the phosphor.

Please replace paragraph 39 with the following paragraph:

The mixture was fired under an atmosphere comprising 2 percent (by volume) hydrogen in nitrogen, at a temperature of 1550 $^{\circ}\text{C}$, for about 4 hours. The phosphor has a formula of $(\text{Sr}_{0.7}\text{Eu}_{0.3})(\text{Mg}_{0.7}\text{Mn}_{0.2}\text{Zn}_{0.1})\text{Al}_{10}\text{O}_{17}$. The excitation and emission spectra of this phosphor were substantially indistinguishable from those of $(\text{Sr}_{0.7}\text{Eu}_{0.3})(\text{Mg}_{0.8}\text{Mn}_{0.2})\text{Al}_{10}\text{O}_{17}$.

Please replace paragraph 45 with the following paragraph:

The firing temperature is in the range from about 1000 $^{\circ}\text{C}$ to about 1600 $^{\circ}\text{C}$. A firing time can be selected in the range from 1 minute to about 10 hours. The firing time depends, to some extent, the same factors that are discussed in connection with the dry method of preparation.

Please replace paragraph 47 with the following paragraph:

In another embodiment, oxides or other oxygen-containing compounds of at least magnesium; europium; manganese; at least one alkaline-earth metal other than manganese; and at least a Group-IIIB metal selected from the group consisting of Al, Ga, and In are dissolved in an acidic solution, such as hydrochloric acid, nitric acid, sulfuric acid, citric acid, or acetic acid. The strength of the acidic solution is chosen to rapidly dissolve the oxides or the oxygen-containing compounds, and the choice of the strength of the acidic solution is within the skill of a person skilled in the art. Ammonium hydroxide is then added in increments to the acidic solution containing said magnesium; said europium; said manganese; said at least one alkaline-earth metal; and said at least a Group-IIIB metal while stirring to precipitate a mixture of hydroxides of said magnesium; said europium; said manganese; said at least one alkaline-earth metal; and said at least a Group-IIIB metal. An organic base; such as methanolamine, ethanolamine, propanolamine, dimethanolamine, diethanolamine, dipropanolamine, trimethanolamine, triethanolamine, or tripropanolamine; may be used in place of ammonium hydroxide. Alternatively, an ester of an organic acid may be used to carry out the precipitation; such as methyl, ethyl, or propyl esters of acetic acid, propionic acid, butyric acid, oxalic acid, malonic acid, succinic acid, or glutaric acid; dimethyl, diethyl, dipropyl esters of oxalic acid, malonic acid, succinic acid, or glutaric acid. The precipitate is filtered, washed with deionized water, and optionally dried. The dried precipitate is ball milled or otherwise thoroughly blended and then heated in a reducing atmosphere at a temperature in the range from about 1000 $^{\circ}\text{C}$ to about 1600 $^{\circ}\text{C}$, preferably from about 1400 $^{\circ}\text{C}$ to about 1600 $^{\circ}\text{C}$. Alternatively, the wet precipitate can be heated first, and then ball milled or otherwise thoroughly blended afterward.

Please replace paragraph 48 with the following paragraph:

Each of samples S10, S20, S30, and S40 of phosphors of the present invention (shown in Table 1 above) can be blended with the phosphor $(\text{Sr,Ca,Mg,Zn})_2\text{P}_2\text{O}_7\text{:Eu}^{2+},\text{Mn}^{2+}$ (emitting yellow-orange light, hereinafter called "SPP") and the phosphor $(\text{Sr,Ba,Ca})_5(\text{PO}_4)_3(\text{Cl,F,OH})\text{:Eu}^{2+}$ (emitting blue light, hereinafter called "SECA") to provide the same light emitted by a commercial phosphor blend consisting of SPP and $\text{Sr}_4\text{Al}_{14}\text{O}_{25}\text{:Eu}^{2+}$ (hereinafter called "SAE"). As used herein and throughout the description, elements listed within parenthesis and separated by commas of a given formula refer to at least one of the elements contributing by an amount mentioned in the subscript, outside of the parenthesis. The "at least one" as used above refers to one or a combination of the elements. The light emitted by these blends have substantially the same CIE chromaticity coordinate of $x = 0.387$ and $y = 0.41$, and a correlated color temperature of about 4100 K. Such light characteristics can be obtained with a composite spectrum consisting of 71 % contribution from SPP, 9 % contribution from SECA, and 21 % contribution from a phosphor selected from the group consisting of S10, S20, S30, and S40. The luminosity of each phosphor blend is shown in Table 2.

Please replace paragraph 56 with the following paragraph:

Incorporation of a phosphor of the present invention in a device comprising a radiation source that emits in the near UV-to-blue wavelength range (from about 250 nm to about 480 nm) provides a visible light source that uses electrical power efficiently. In one embodiment, the radiation source emits radiation having wavelengths in a range from about 250 nm to about 420 nm. In one embodiment, the radiation source is a UV/blue LED. The visible light source may be fabricated to provide a point source device by using one such UV/blue LED or a large-area lighting device by using a plurality of such UV/blue LEDs.

Please replace paragraph 57 with the following paragraph:

In one embodiment of the present invention as shown in Figure 6, a light source 10 emitting visible light comprises a UV/blue LED 100 emitting light at least in a portion of the wavelength range of about 250 nm to about 480 nm and a phosphor of the present invention. The UV/blue LED 100 is mounted in a cup 120 having a reflective surface 140 adjacent LED 100. Blue LEDs suitable for white light-emitting devices are InGaN semiconductor-based LEDs such as those of U.S. Patent 5,777,350 mentioned above, which is incorporated herein by reference. Other UV/blue LEDs also may be used, such as LEDs based on GaN semiconductor doped with various metals to provide a large band gap. Electrical leads 150 and 152 are provided to supply electrical power to the LED 100. A transparent casting 160 comprising an epoxy, a silicone, or glass 180 in which there are dispersed substantially uniformly particles 200 of a phosphor of the present invention. Then a molded seal 220 of a transparent material, such as an epoxy or a silicone, is formed around the assembly of LED and phosphor casting to provide a hermetic seal thereto. Alternatively, the phosphor particles may be applied on the LED 100 or dispersed in only a portion of the transparent casting 160. Other transparent polymers also may be used to form the transparent casting. In addition, particles of a light scattering material, such as TiO_2 or Al_2O_3 , may be included in the transparent casting among the phosphor particles to improve the uniformity of the light emitted from the light source 10. The composition of the InGaN active layer of the LED and the quantity of the phosphor applied in the casting may be chosen such that a portion of the blue light emitted by the LED that is not absorbed by the phosphor and the broad-spectrum light emitted by the phosphor are combined to provide the white light source 10 of a desired color temperature and CRI.